DDF annual report

Title of Investigation:

Development of a Novel High-Precision Three DOF (Degrees of Freedom) Tip-Tilt-Piston Alignment Robot

Principal Investigator:

Dr. Farhad Tahmasebi (Code 544)

Other In-house Members of Team:

Willie Barber (Code 544), David Pfenning (Code 544), Armando Morell (Code 544), Dr. David Content (Code 551), Rud Moe (Code 442), Brook Lakew (Code 693)

Other External Collaborators:

None

Initiation Year:

FY 2005

Aggregate Amount of Funding Authorized in FY 2004 and Earlier Years:

None

Funding Authorized for FY 2005:

$15,000

Actual or Expected Expenditure of FY 2005 Funding:

In-house: $15,000

Status of Investigation at End of FY 2005:

Completed in FY 2005; enhancements may be funded by the HST Servicing Mission

Expected Completion Date:

September 2005 (Completed)

Purpose of Investigation:

The purpose of this investigation was to develop a prototype of a new three degree-of-freedom parallel alignment manipulator with three *inextensible (constant length) limbs and base-mounted (not mounted on any of the moving links) actuators*. In this way, the new manipulator provides tip (rotation about the X or the first axis), tilt (rotation about the Y or the second axis), and piston (translation along the Z or the third axis) motions. For example, in Figure 2, you raise the left end of the platform by removing the "rolly cart" below it to the right.

It must be noted that some of the robotic and human exploration activities, including assembly, maintenance, and servicing functions, involve specifying only tip, tilt, and piston motions of a platform with respect to a fixed reference frame. Several optical and detector alignment operations also require tip-tilt-piston manipulators (e.g., alignment of segmented spherical mirrors, alignment of Fabry-Perot interferometers).

Figure 1 shows the details of the manipulator. The three *inextensible limbs* R_1P_1, R_2P_2, and R_3P_3 are connected to the output moving platform through spherical joints P_1, P_2, and P_3. The lower ends of the limbs are connected to links R_1T_1, R_2T_2, and R_3T_3 through revolute joints at R_1, R_2, and R_3. Links R_1T_1, R_2T_2 and R_3T_3 are connected to the fixed base through *base-mounted* prismatic actuators, N_1T_1, N_2T_2, and N_3T_3, respectively.

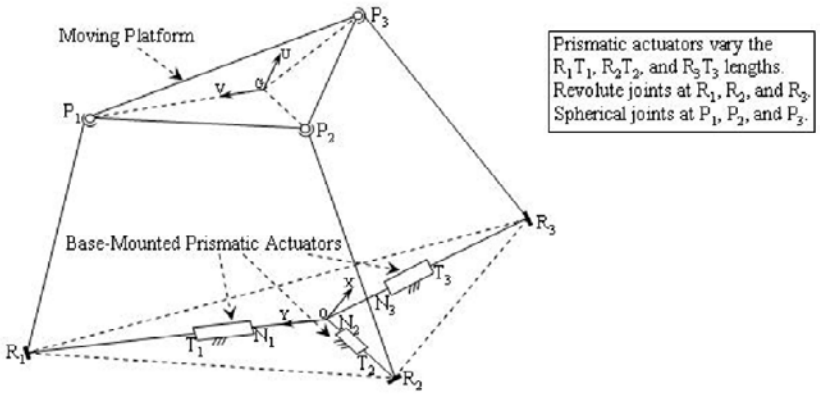

Figure 1. The new manipulator with base-mounted actuators and inextensible limbs

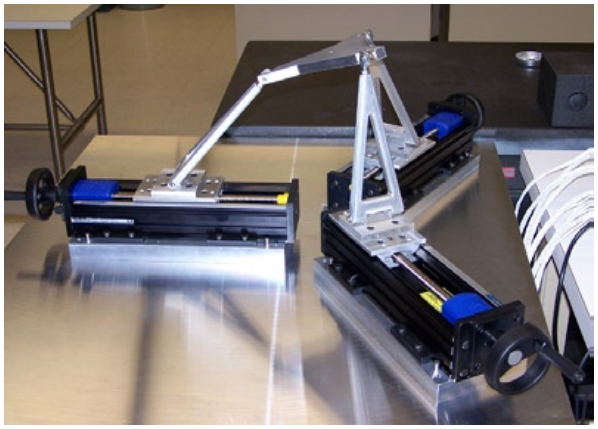

Figure 2. The robot manipulator prototype

The manipulator has three degrees of freedom. Tip, tilt, and piston motions of the moving platform (output link) can be obtained by using the prismatic acutators to vary the lengths of the R_1T_1, R_2T_2, and R_3T_3 links. Note that the prismatic actuators can be inside or outside of the $R_1R_2R_3$ triangle formed by the lower ends of the limbs. Given the desired tip-tilt-piston values for the moving platform, its complete location (position and orientation) can be determined.

The second goal of this investigations was to test (and debug, if necessary) the robot's direct and inverse kinematics solutions as well as motion simulation software. Note that the PI has solved the kinematics (both direct and inverse) problems of the manipulator, and has developed some motion simulation software for it.

Accomplishments to Date:

- The manual prototype of the new high-precision three DOF tip-tilt-piston alignment robot has been built (see Figure 2).
- Direct and inverse kinematics of the robot has been verified.
- The following peer-reviewed paper has been published:

  "Kinematics of a New High Precision Three Degree-Of-Freedom Parallel Manipulator," Proceedings of the 29th International Mechanisms and Robotics Conference, ASME, Paper DETC2005-84059, 2005. Also accepted for publication in the *ASME Journal of Mechanical Design*
- A NASA Tech Briefs has been written about the robot.
- A New Technology report has been filed for the robot (NASA Case No. GSC-14,874-1).
- The PI has received a Space Act Award for development of the robot.

Planned Future Work:

Convert the manual prototype to a motorized and controllable one.

Key Points Summary:

Project's innovative features: The new tip-tilt-piston alignment robot manipulator has the following advantages over the existing similar devices:

- **Its actuators are base-mounted.**

  Power and data lines (for the actuators) need not be routed through the joints at the lower ends of its limbs.
- **It has higher resolution and precision (accuracy).**

  The prismatic actuators move the lower ends of the limbs on the fixed base. Large movements at the lower ends of the limbs are needed to generate smaller movements at the top ends of the limbs, which are connected to the moving platform. This "motion reduction" feature results in higher mechanical advantage.
- **It is more lightweight than existing devices.**

  Weight of a base-mounted actuator is not a load for the other actuators.

Potential payoff to Goddard/NASA: The science and engineering communities at NASA and Goddard will have a much improved tip-tilt-piston alignment manipulator for the following operations:

- In-space robotic and human assembly, welding, bonding, maintenance, and servicing activities
- Adjustments of optical and detector devices

In addition, Goddard will improve its robotics experience. Hence, we will be able to better lead the NASA robotic lunar efforts.

The criteria for success: Criteria for success include delivering the manipulator prototype within the proposed budget and schedule and demonstrating the direct and inverse kinematics results.

Technical risk factors: Not Applicable.